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Lowell Observatory
Flagstaff, Arizona 86001

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Title

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1 January 1975 through 30 June 1975

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(NASA-CR-143442) [ASTEROID OBSERVATIONS AND PLANETARY ATMOSPHERES ANALYSIS] Semiannual Status Report, 1 Jan. - 30 Jun. 1975 (Lowell Observatory) 11 p HC $3.25 CSCL 03A

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Principal Investigator

Robert Millis
Robert L. Millis
Co-Investigator

ELG Bowell
Edward L. G. Bowell
Co-Investigator

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I. PERSONNEL

Dr. W. A. Baum, Director of the Planetary Research Center and Principal Investigator, four-fifths time
Dr. R. L. Millis, astronomer and co-investigator
Dr. E. L. G. Bowell, astronomer and co-investigator
Dr. L. H. Wasserman, post-doctoral fellow
Ms. L. A. Riley, research associate, half time
Mr. L. J. Martin, observer and Patrol film editor
Mr. C. F. Capen, observer and film analyst
Mr. D. T. Thompson, observer and data analyst, four-fifths time
Mr. S. E. Jones, chief technician
Ms. H. S. Horstman, research assistant and secretary
Ms. H. M. Ferguson, research assistant
Mr. J. H. Chastain, electronics and computer technician
Mr. H. W. Culp, instrument maker
Mr. F. Macias, maintenance man, half time
Ms. H. J. Scheele, bookkeeper, half time

Except as otherwise indicated, the personnel listed above were full-time under this grant. Mr. Macias replaced Mr. C. F. Mackaman during this report period. Temporary tasks were performed by Ms. K. A. Duck, student assistant. Other Observatory employees not paid under this grant, such as Dr. J. S. Hall, Dr. O. G. Franz, Dr. G. W. Lockwood, Mr. H. L. Giclas, Ms. M. L. Kantz, Mr. K. L. Williams, and Mr. N. C. Crowfoot, have participated in some of the observations or analyses mentioned in this report.

II. OVERVIEW AND SUMMARY

Observations. Precise light curves of Eros provided information about the surface materials, shape, and rotation axis. Thirty other asteroids have been observed photoelectrically and classified with regard to surface characteristics. Trial observations with our modified polarimeter yielded more precise results than obtained earlier. Photographs of eighteen asteroids and four comets provided accurate positions on various dates. Photometry of the Saturn satellite Iapetus revealed a dimming of the fainter hemisphere during the last three years. Electronographic images of the Uranus and Neptune satellites were obtained experimentally with a Spectracon tube to assess photometry by that method. Deconvolved area scans of Uranus revealed limb brightening in two methane bands. Planetary Patrol photographs of Venus were obtained on 46 nights centered around May, and preparations are under way for a major Patrol campaign on Mars and Jupiter this coming Fall. Some fundamental observations were made that bear on the constancy of physical constants and have important implications concerning the constancy of Solar System dimensions during the time since its formation. Papers on several of these topics are in process.

Data Analyses. UBV photometry of the Galilean satellites in 1973-74 has been completely analyzed and accepted for publication. The reduction and analysis of the 1973-74 mutual eclipse and occultation observations of the Galilean satellites have been continued. An improved magnitude and color index for Mimas were derived from 1974 area scans. Progress has been made in the digitization and computer differencing of Jupiter images for improving the limits of cloud flow detection, and two papers were given at meetings about this program. New results concerning the relative motions of red and blue features in the Jovian cloud deck show that neither systematically outruns the other. Polarimetric results showing the non-existence of fine structure on Jupiter are in preparation for publication. The behavior of the Martian north polar hood during its early stages has been analyzed in three colors, and a paper has been prepared for publication. The recession of the north polar hood during Martian dust storms has been discussed in another paper that is now in press. Hourly behavior of the 1973 Martian dust storm has been mapped in both red and blue light, and a paper is nearly ready for publication. Daily Martian cloud mapping for 1971 is continuing, and a new compilation of the existing maps for 1969 is also under way. A microphotometric study of seasonal contrast changes in three regions of Mars is nearing completion.

Instrumentation and Technique. A special photomultiplier tube with a suppressor grid was incorporated into a pulse-counting photometer with special added circuitry for carrying out the observations concerning the constancy of solar system dimensions over cosmic time. For the photometry experiment involving the satellites of Uranus and Neptune, a Spectracon image tube and its focusing solenoid were mounted on an offset guider and were connected with suitable power supplies. Experiments were carried out to improve the accuracy and efficiency of photographic image compositing (image stacking). Improvements were undertaken at two telescopes devoted to planetary observations.

Other Activities. Guest investigators and visiting scientists have been received as usual, and planetary photographs have been supplied to various outside investigators. Six guest investigators were each at the Planetary Center for a month or more. One of our staff continues to serve on several teams and committees in support of NASA's space program. Two full research papers and four shorter publications appeared in print during this six-month period; three more were in press as of June 30th; six papers were presented at society meetings by members of the staff.

III. RESEARCH PROGRAM, OBSERVATIONS

Our research projects are divided into three main sections (III, IV, V) of this report. All have entailed observations, data analyses, and (at some point in their history) instrumentation. Only those involving observations during this report period are described in the present section. Other projects that were concerned primarily with data analysis are covered in section IV. Section V provides further details about instrumentation not covered under III or IV.

Photometry of Asteroids. Millis and Bowell conducted photometry of asteroid 433 Eros on 10 nights in January, February, and March. With the assistance of Thompson, these observations and those from 1974 have been completely reduced. The light curves are precise and detailed, making it possible to deduce a lot of information about the surface material, shape, and rotation axis of Eros. More about these results will be provided in the next Status Report, and a paper giving details will be included in the forthcoming special issue of Icarus devoted to Eros.

Bowell has generated ephemerides for over 300 asteroids observable in 1975, using a new method that allows rapid and simple position computation with an uncertainty of ±2 arcminutes throughout the apparition. He calculates "quasi-osculating" elements, which are the elements that best represent the geocentric coordinates of an asteroid and implicitly include effects due to planetary perturbations and light time. Finding charts are generated on the computer.

UBV magnitudes of 30 asteroids have been reliably determined, and a paper has been prepared by Bowell in collaboration with B. Zellner, W. Wisniewski, and L. Andersson. Figure 1, which summarizes the available observations to date for 91 asteroids, shows how UBV magnitudes alone may be used to classify them into three groups on the basis of laboratory data: carbonaceous (C), silicaceous (S), and unclassifiable (U).

Photoelectric Polarization Measurements of Asteroids. Using the rotating half-wave plate attachment on Hall's dual-channel polarimeter, together with a PDP-11 data system, Bowell made some trial observations of the 12th-magnitude asteroid 356 Liguria in January. The results, which were displayed in our FY 76 proposal submitted in February, showed a well-defined curve yielding the polarization with a precision in the neighborhood of 0.001.

Positions of Asteroids and Comets. Using the 13-inch wide-field photographic refractor ("Pluto Telescope"), Giclas obtained plates with which he and Kantz have determined a number of asteroid and comet

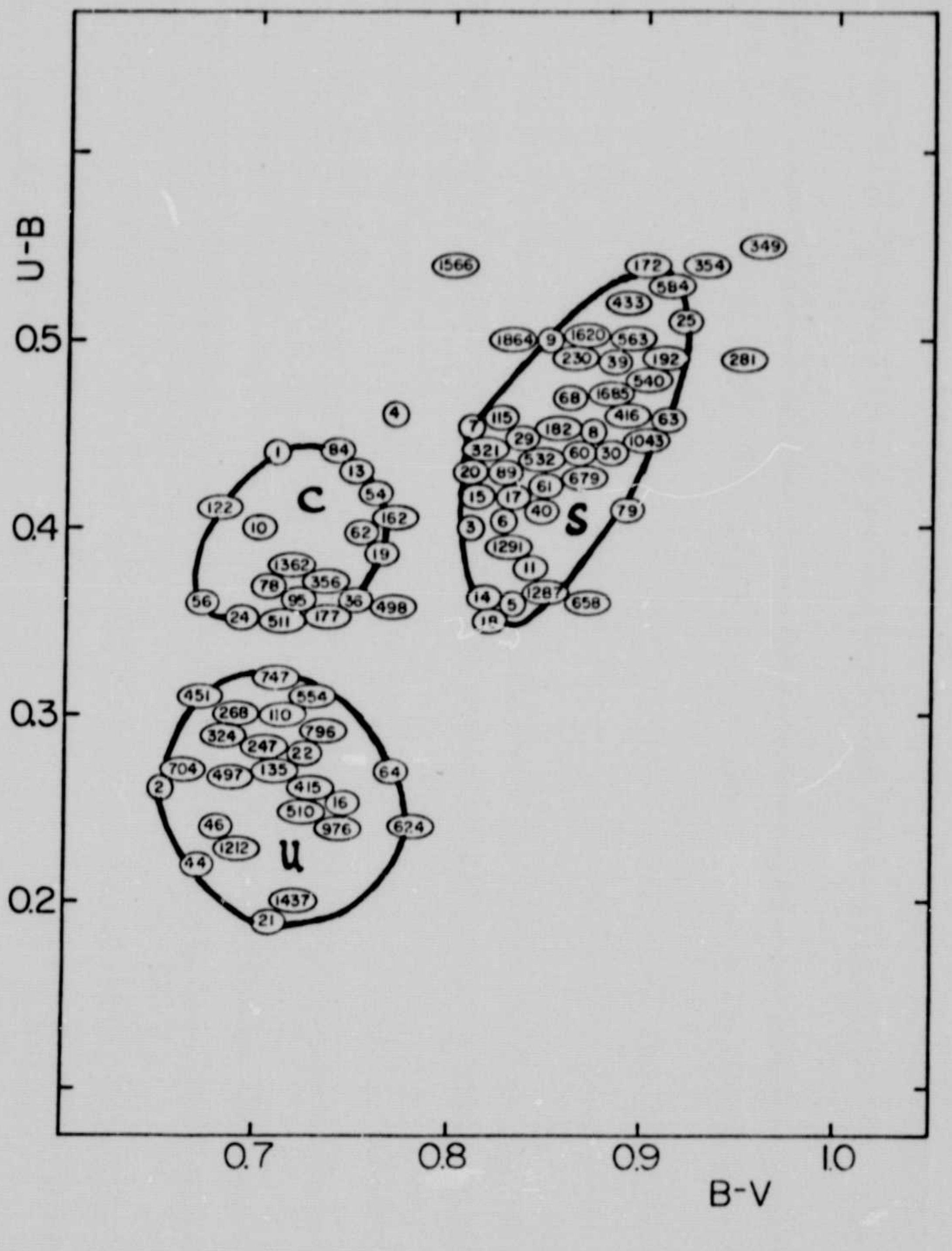

U-B
B-V
0.5
0.4
0.3
0.2
0.7
0.8
0.9
1.0
C
S
U
1566
172
354
349
584
433
25
1864
9
1620
563
230
39
192
281
540
68
1685
4
416
63
7
115
182
8
1043
321
29
60
30
532
20
89
679
15
17
61
79
3
6
40
1291
11
14
5
1287
658
18
1
84
13
54
122
10
162
62
19
1362
78
356
95
36
498
56
24
511
177
747
451
554
268
110
796
324
247
22
704
497
135
64
2
415
16
510
46
976
624
1212
44
1437
21

Figure 1.

positions. During this report period, these included seven accurate positions of Eros; two each of 1949OA, 1931VD, and 804; and single determinations of 14 others. These results, together with 32 asteroid positions from old plates and a listing of 1100 plate centers in the Lowell collection, have been furnished to Dr. P. Herget in Cincinnati. Comet positions sent to the Central Bureau of Astronomical Telegrams during this report period have included Schwassman-Wachmann II, 1975a Boethin, 1975b Kohoutek, and 1975d Bradford.

Photometry of Outer Planet Satellites. Millis observed the Saturn satellite Iapetus on three nights in January and February. Taken together with all his photometry of Iapetus, dating back to 1971, the observations show that the fainter hemisphere has dimmed about 10 percent in the last three years, while the brighter hemisphere has remained essentially constant in brightness over the entire period of observation.

In somewhat the same vein, we should mention Lockwood's result on Titan, even though his project (the Lowell Solar Variation Program) is wholly supported by NSF. Photometry of Saturn this past winter, taken together with data from two previous apparitions, shows a steady brightening trend of about 0.02 magnitude per year. Details were presented in a paper at the Maryland DPS meeting and are summarized in a B.A.A.S. abstract.

Baum used a Spectracon tube in June to record photometric images of the satellites of Uranus and Neptune. The Spectracon is an electronographic image tube described by McGee, Khogali, Ganson, and Baum in Advances in Electronics 22, 11, 1966. The Uranus and Neptune observations were obtained in the course of a joint observing session at Lowell with N. K. Reay, B. L. Morgan, S. Worswick, and D. Youll, all from the Astronomy Group of Imperial College London. The satellite observations were in the nature of an experiment to find out whether an electronographic image (which is photometrically linear) might provide an effective method for the photometry of close satellites against the scattered light from the parent planet. Until the Spectracon images have been digitized with our PDS-PDP/11 microdensitometer-computer system, we cannot really judge the success of the experiment.

Limb Brightening on Uranus. In May and June, Franz and M. J. Price (Planetary Science Institute) made 100 Å-band area scans of Uranus at eight selected wavelengths between 5600 Å and 7500 Å with the Perkins reflector. Deconvolution of the scans yields limb brightening in the methane bands at 6200 Å and 7300 Å.

International Planetary Patrol. Patrol operation at Lowell from April 22 through June 6 resulted in 64 usable photographic sequences of Venus obtained on 34 out of the 46 scheduled nights. This material, obtained by Martin, Capen, Ferguson, and Thompson, provides relatively good synoptic coverage. The image sequences will be of use to experimenters who participated in a program of simultaneous collaborative observations during May, centered within our Patrol interval.

Preparations were made for full Patrol network operation during the apparitions of Jupiter and Mars this Fall. Local Patrol observers will be on regular duty from early September to early February at Lowell (Arizona), Mauna Kea (Hawaii), and Perth (Western Australia). In addition, we have made arrangements to send Ferguson for 10 weeks of Patrol observing at Cerro Tololo (Chile). To augment the uninterrupted Patrol schedule at these four places, and particularly to fill the gap in longitude coverage between Perth and Cerro Tololo, we are making informal arrangements for low-cost partial coverage at Bologna (Italy) and at Athens (Greece). We expect to supply only film, filters, miscellaneous materials, and postage to these voluntary observers; they will not be using standard Patrol equipment and procedures.

The Constancy of Solar System Dimensions over Cosmic Time. Baum and R. F. Nielsen (Copenhagen University Observatory) made some fundamental observations concerning the nature of photons and bearing on the constancy of various physical constants. The observations were made photoelectrically in March and April with the Perkins reflector. Taken together with other results, these observations appear to imply that cosmic measuring sticks have not changed with time. This means that any apparent secular change of Solar System dimensions, as claimed by van Flandern on the basis of lunar occultation data, would have to be due to a secular decrease in the gravitational constant G and not due to a secular shrinkage of cosmic measuring sticks, which ultimately rest on the Bohr radius. In other words, there is a fundamental ambiguity between a change in G and a change in the Bohr radius, and the new result of Baum and Nielsen argues for the constancy of the Bohr radius.

Very briefly, the new findings (and other links in the chain of reasoning) are as follows: using a special photomultiplier tube with which incident photons of differing energy can be distinguished (see section V), Baum and Nielsen compared light from distant galaxies (redshifts to 0.14) with light from nearby galaxies. Due to great differences in travel time, photons from distant galaxies are much older than those from sources nearby. Within the errors of measurement, old photons of a select wavelength were found to have the same energy as young photons of the same wavelength. Since $E\lambda = hc$, the data show that any residual difference in hc at the time of photon arrival must be small in comparison with the redshift z. But the velocity of light c is evidently not z-dependent, because the aberration constant is the same for distant galaxies as for stars, so it follows that Planck's constant h, by itself, does not depend on z. The excellent agreement of 21-cm redshifts with optical redshifts indicates that the Summerfeld fine-structure constant $2\pi e^2/hc$ is not z-dependent, so our hc result above leads to the same conclusion concerning e alone. Since black-body redshifts do not differ significantly from spectroscopic redshifts, one can further deduce that

the electron mass m and the Bohr radius should also be independent of z. If photons are unaltered between emission and arrival, Baum and Nielsen's result thus implies within errors of measurement that the physical constants h, c, e, m, and the Bohr radius are all truly constant with time. That leaves G to be the only available culprit if there is indeed an apparent secular change of Solar System dimensions.

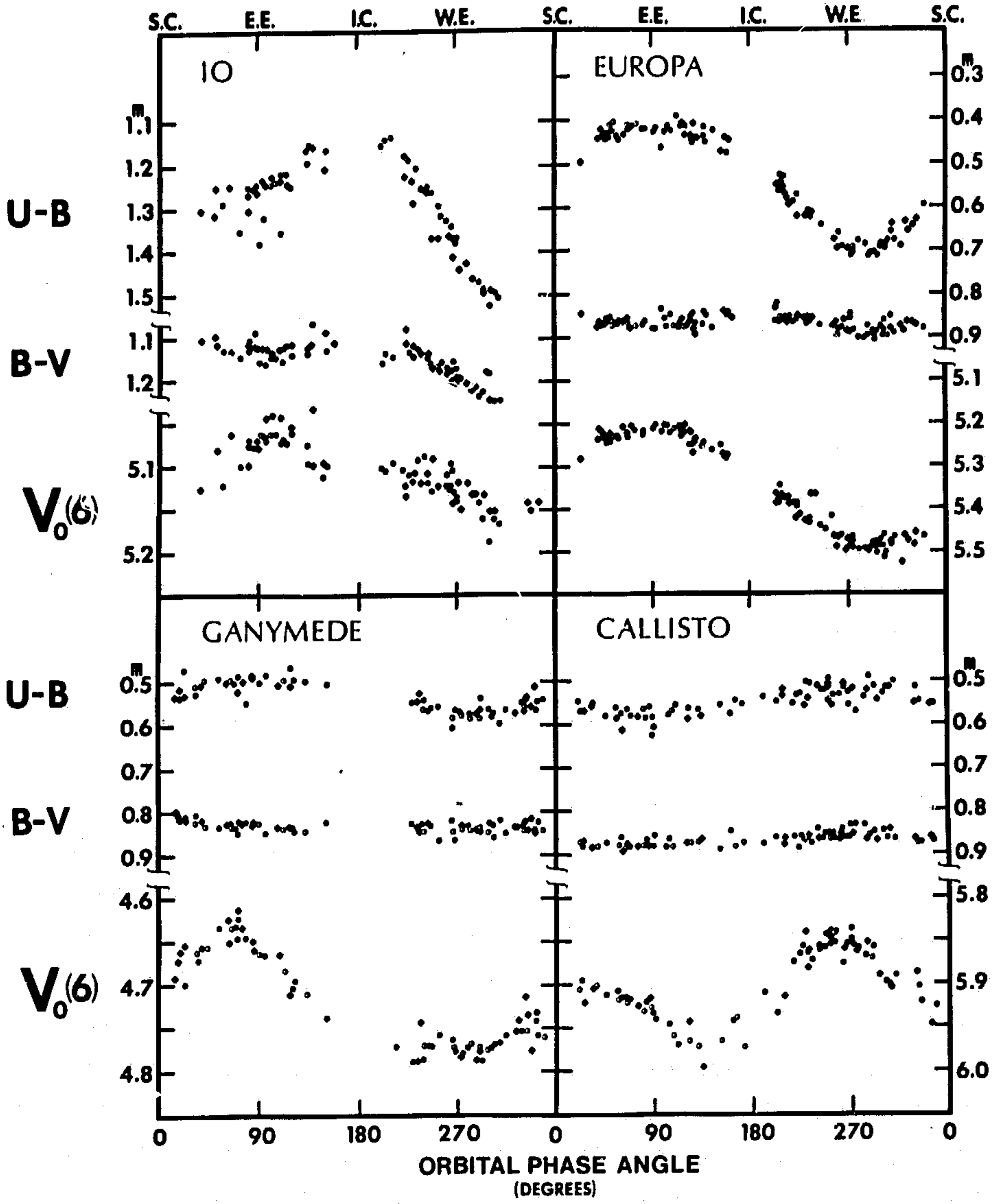
IV. RESEARCH PROGRAM, DATA ANALYSES

Photometry of Outer Planet Satellites. Millis and Thompson completed reduction and analysis of their 1973/74 UBV Galilean satellite photometry during this report period. A paper describing the results of these observations has been accepted for publication in Icarus. Briefly, Millis and Thompson have determined the improved rotational light and color-index curves shown in Figure 2, they have derived the brightness dependence of various faces of the satellites on solar phase angle, and they have detected an apparent secular brightening of the satellites between 1973 and 1974 somewhat similar to Lockwood's result for Titan.

Millis, Thompson, and Crowfoot continued the reduction and analysis of the 1973-74 mutual eclipse and occultation observations obtained with our photometers at Lowell, Cerro Tololo, Perth, and the Virgin Islands. They developed a curve-fitting computer program with which they are now obtaining midpoint timings, depths of the minima, east-west asymmetries, and north-south differences of albedo and color. All results relating to ephemerides and diameters have been forwarded to Aksnes and Franklin of Smithsonian Astrophysical Observatory. The comparison of two or more light curves for the same event helps determine what is real and what is noise, and we are consequently skeptical of the detailed albedo maps that some others have published on the basis of much less data.

Wasserman, in collaboration with J. L. Elliott (Cornell), J. Veverka (Cornell), and W. Liller (Harvard) has also analyzed light curves of mutual occultations and eclipses. Fitting their data to idealized models, they find that models which include limb darkening on Europa fit the data somewhat better than do uniform-disk models. A paper on this work has been accepted for publication in Icarus.

Photoelectric area scans of Mimas of last Fall were analyzed by Franz and reported at the Maryland DPS meeting. The new color index, $B-V = 0.65$, resembles that of other inner satellites of Saturn, while the new magnitude reduced to mean opposition distance, $V_0 = 13.0$, leads to a more plausible mean density than implied by previous data.


S.C.
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GANYMEDE
CALLISTO
U-B
B-V
$V_0(6)$
U-B
B-V
$V_0(6)$
0
90
180
270
0
90
180
270
0
ORBITAL PHASE ANGLE
(DEGREES)

Figure 2.

Cloud Motions in the Jovian Atmosphere. Wasserman and Baum reported at the Maryland DPS meeting on the methods being implemented here for improving the limit of detection of motions in the Jovian atmosphere, and a summary appears in the Abstracts of that meeting. A second report, with more emphasis on Jupiter science, was presented by Baum, Wasserman, and Inge at the Jupiter Conference in Tucson in May. Our Tucson paper included some new results concerning the relative motions of red and blue features, showing that neither systematically outruns the other. This does not confirm Layton's (Icarus 15, 480, 1971) tentative evidence for the faster flow of red features, which was interpreted to imply vertical shear.

As outlined in our FY 76 proposal, our new approach involves the comparison of Jupiter photographs with one another by means of a digitizing microphotometer and a computer, so that all non-reversable changes that have occurred in the time interval between two photographs can be recognized if they are above the limit of photographic detection.

During the present report period, Wasserman has written or adapted software for scanning images, editing them, transforming them to a coordinate system suitable for superposition, and playing back a display of the differences. A lot of time has been spent by Chastain in putting the system into operation and in tracking down a rather large number of failures in the equipment. The photographic playback portion of the PDS system, as originally designed by Boller and Chivens, has proved unsatisfactory when slit sizes suitable to our study are used, but Jones and Baum have worked out some changes in the playback diode and optics that have cured most of the problem. It has proved difficult to obtain adequate help from Boller and Chivens, and our PDS problems are not fully solved yet.

Hall and Riley completed reduction of their polarimetric observations of Jupiter. They were searching for any fine structure that might be related to cloud features, but they found none. A paper is in preparation for submission to Icarus.

Martian Clouds and Dust Storms. A paper by Martin and McKinney appeared in Icarus during this report period. It was concerned with the day-to-day behavior of the north polar hood in 1969, as recorded in blue light. No dust storm was in progress at that time. A second paper has been prepared by Martin and McKinney covering the same time interval, but treating the behavior of the north polar hood as seen in green and red light.

Using Patrol photographs, Martin completed his study of the behavior of the north polar hood of Mars during dust storms and presented a paper on that subject at the Maryland DPS meeting. A full

paper is now in press and will soon appear in Icarus. He finds that the apparent boundary of the north polar hood has receded when major dust storms have occurred. One cannot assume that the hood is still there, blocked from view by a higher blanket of dust. The dust will certainly affect the temperature profile of the atmosphere and thereby affect the hood.

Martin has also completed the mapping of the developing stages of the 1973 Martian dust storm, showing its hourly behavior on the same basis as his study of the 1971 storm. As an example, Figure 3 shows red-light and blue-light maps for Days 7 and 8 of the 1973 storm. Preparation of a paper for submission to Icarus was well along at the end of this report period.

Two other Mars cloud studies are continuing. One is a general mapping of all 1971 clouds in all colors at all latitudes by Martin and Ferguson. The other is a compilation by Martin and McKinney of the 1969 cloud maps (prepared earlier) in such a way as to show the pattern of cloud development during each day. An earlier paper by Martin and Smith (Publ. Astron. Soc. Pacific 83, 606, 1971) based on the same material showed only the overall distribution for that season, and more recently our related papers have concerned only the polar hood.

Regional Contrast Variations on Mars. Capen has continued his microphotometric study of season-to-season contrast effects. A third group of areas on Mars has been added to the two groups mentioned in the previous status report. Areas within each group are being compared with one another in two selected time intervals, one from 1971 and the other from 1973, when phase angles and sub-Earth latitudes were almost identical, but when the seasons differed by about 90° in L_s. By comparing the brightnesses of individual areas with respect to the mean of the neighboring group, one can determine which individual areas are really varying.

V. INSTRUMENTATION AND TECHNIQUE

The Constancy of Solar System Dimensions over Cosmic Time. Figure 4 shows a general schematic diagram of the special pulse-counting photometer, assembled by Baum and Nielsen with the help of Culp and Chastain, for investigating the constancy of the physical constants. It included provision for offsetting to faint (invisible) objects for the required sources of old photons. The special photomultiplier itself, obtained from EMI by Nielsen for another purpose, has a mesh 5 mm behind the photocathode. The application of small voltages between

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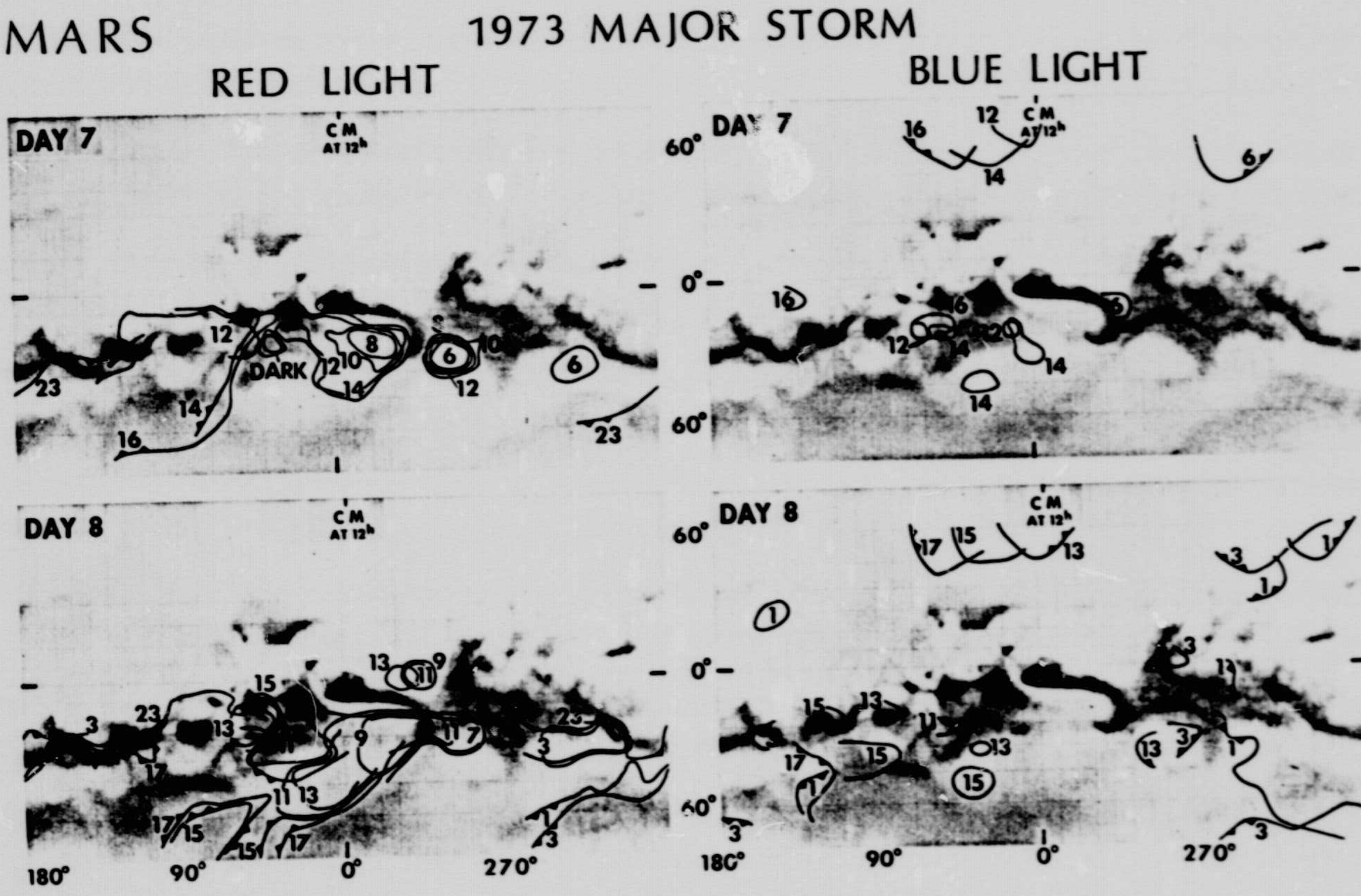
MARS
1973 MAJOR STORM
RED LIGHT
BLUE LIGHT
DAY 7
DAY 8
CM AT 12h
DARK
60°
0°
180°
90°
0°
270°

Figure 3.

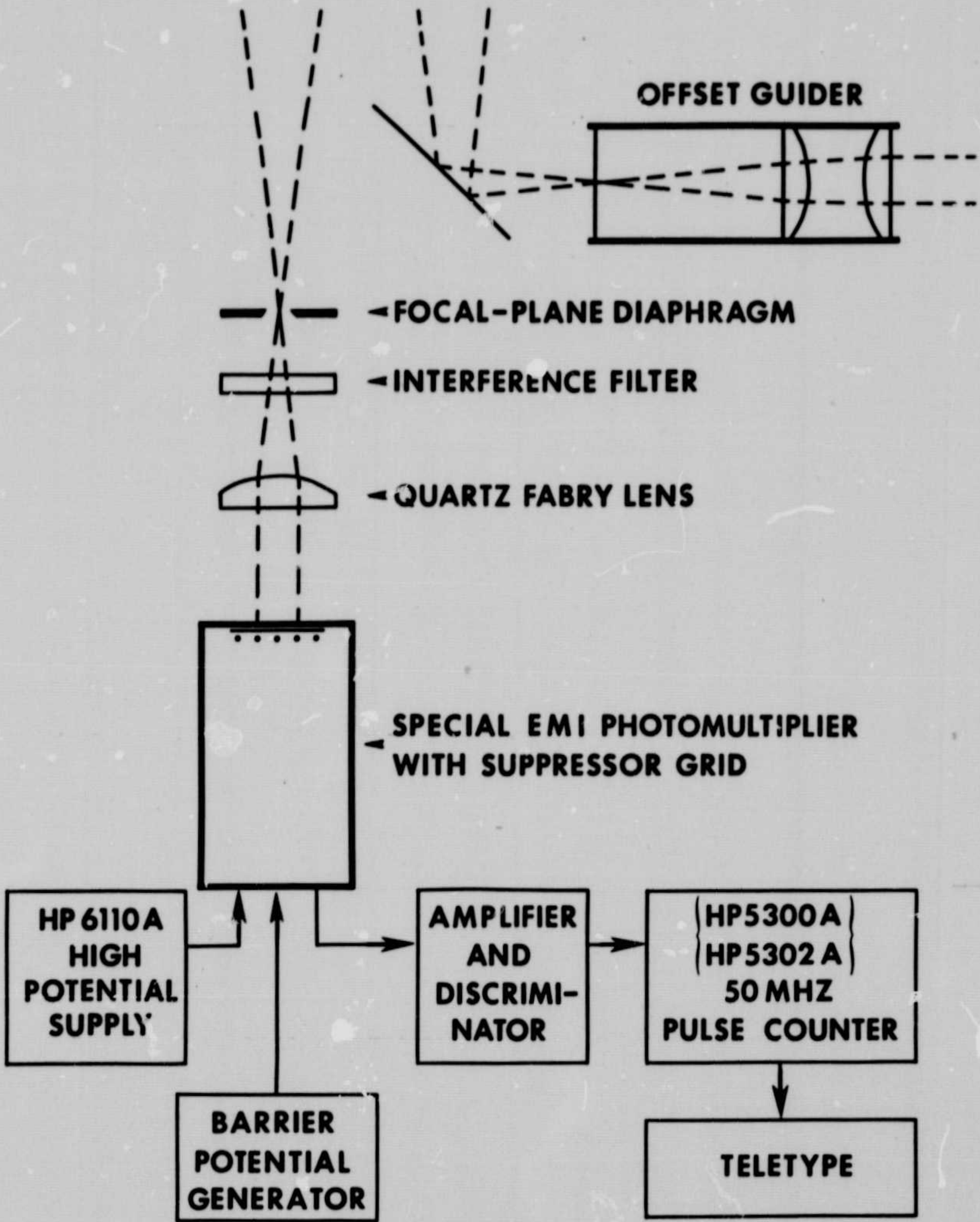
OFFSET GUIDER
FOCAL-PLANE DIAPHRAGM
INTERFERENCE FILTER
QUARTZ FABRY LENS
SPECIAL EMI PHOTOMULTIPLIER
WITH SUPPRESSOR GRID
HP 6110A HIGH POTENTIAL SUPPLY
BARRIER POTENTIAL GENERATOR
AMPLIFIER AND DISCRIMINATOR
HP5300A
HP5302A
50 MHZ PULSE COUNTER
TELETYPE

Figure 4.

photocathode and mesh permits the sorting of photoelectrons according to energy, which in turn distinguishes incident photons of differing energy so as to obtain the results described under section III of this report. The selectable potential difference between photocathode and mesh is provided by a small solid-state barrier potential generator.

Photometry of Outer Planet Satellites. The Spectracon equipment used for photometric imaging of the satellites of Uranus and Neptune included an offset guider, a Spectracon tube, a focusing solenoid surrounding the tube, a shutter and filter assembly, a high-voltage supply (40 kv), a solenoid current supply, and a water-circulation system for solenoid cooling. The Spectracon tube and associated power supplies were provided by the Imperial College group collaborating with Baum in this experiment, while the offset guider, cooling system, and miscellaneous hardware were prepared at Lowell by Baum with some help by Jones and Culp. Images were recorded by electron impact on Ilford G-5 nuclear track emulsion on a mylar backing. The Spectracon tube itself consists of a photocathode at one end and a thin mica window at the other end through which the photoelectrons are rammed by virtue of the very high potential applied to the tube. The emulsion is simply pressed into contact with the mica by means of a padded roller, which also permits the film to be advanced from one exposure to the next. The focusing solenoid produces a uniform field of about 150 Gauss parallel with the axis of the tube and constrains the electrons to slender helical paths which pass through a node (focus) when the electrons reach the emulsion.

Photographic Compositing. Jones and Ferguson have conducted experiments to determine the positional precision with which images are superimposed during compositing (also known as "image stacking"). Experiments with nine different people operating the compositing equipment showed that almost all positioning errors were less than 0.1 arc-second. We are currently investigating the optimum distribution of exposure times on individual frames that are being stacked, so that each will contribute equally (or unequally, if preferred) to the final composite. A paper concerning these experiments has been scheduled for the San Diego meeting of the AAS Working Group for Photographic Materials in August.

Telescopes. A supplementary declination drive was added to the 13-inch telescope to facilitate positional determinations of moving objects (asteroids and comets). The mechanism for opening and closing shutters has been redesigned for the dome housing the Lowell 24-inch refractor, used for most of our Patrol observations.

VI. PLANNED OBSERVING RUNS

Most observing with our own telescopes at Lowell Observatory is scheduled for specific dates a relatively short time ahead of the actual observing. Asteroid photometry at Lowell will be undertaken by Bowell with the 42-inch telescope, and it will be distributed throughout the year but somewhat concentrated in the winter season when the ecliptic is north of the equator. Further photometry of the satellites of Jupiter and Saturn, mainly by Millis, will also be done with the 42-inch telescope, centered around the Jupiter opposition in October and the Saturn opposition in January. Polarimetry of Mars by Bowell and Thompson, probably with the 42-inch telescope, will be distributed between November and April. Uninterrupted operation of the Patrol camera on the 24-inch Lowell refractor is scheduled to run from September 1 through February 15, simultaneous with similar operation at Mauna Kea and Perth. The Lowell Patrol observers will include Martin, Capen, and Thompson. We have already mentioned the ten-week observing expedition by Ferguson in Chile during the middle of the Patrol interval. Wasserman and Millis are laying tentative plans for photometrically observing the occultation of the third-magnitude star ϵ Geminorum on April 7th (1976) with a telescope somewhere in the southeastern United States. If Baum and Nielsen decide to make further observations bearing on G and the other physical constants for the purpose of reducing limits of uncertainty, they may want to seek time on a larger telescope than those available at Lowell. If such a plan is decided upon, it would most likely take place around next April.

VII. DISTRIBUTION OF PHOTOGRAPHS AND DATA

During this report period, photographic products produced by Jones and Ferguson were supplied in response to 17 requests from publishers, institutions, and individuals. Among these are the following: Dr. Carl Pilcher of the Institute for Astronomy at the University of Hawaii was furnished portions of six rolls of 1974 Jupiter observations in duplicate negative form. Dr. Tony Maxworthy of the University of Southern California was supplied 58 special composite prints of Jupiter representing the principal changes in cloud configurations between 1890 and 1966. A 1974 Jupiter color reconstruction was specially prepared for Dr. Richard Terrile of the Division of Geological and Planetary Science at the California Institute of Technology for comparison with his infrared observations of approximately the same date. A large amount of material was supplied to Mr. Warren Hill of the Public Information Office at Kitt Peak National Observatory for mass reproduction and public distribution by them on our behalf, along with KPNO photo products.

Ephemeris programs for Mars and Jupiter in the form of punched cards were prepared by Horstman for Dr. R. Servajean, Director of the Planetary Data Center at Meudon. Dr. Raymond Hide of the Meteorological Office in England was provided with general catalogues for Saturn 1890-1974, for Jupiter 1890-1968, and for Venus 1895-1974. A catalogue for Saturn 1950-1974 was provided to Dr. Kari Lumme at the University of Massachusetts.

Most incoming photographs are ordinarily from our Patrol stations, but we continue to receive occasional inputs from other places. During this report period, we received 597 composited negatives and positives of 1966-1971 Jupiter, Saturn, Mars, Mercury, Venus, and Uranus from New Mexico State University Observatory. These were added to the Planetary Center collection and entered in our catalogues. Catalogue entries were also made for some photographs remaining on file elsewhere; these included 1972-1973 Jupiter observations at the Tumamoc and Catalina Observatories of the University of Arizona, and 1941-1972 Venus observations on file at Meudon. Horstman continues to carry responsibility for the distribution and cataloguing of all photographic materials.

VIII. GUEST INVESTIGATORS AND VISITORS

Listed chronologically according to arrival, scientific visitors to the Planetary Research Center during this report period included Dr. Aina Elvius of the Stockholm Observatory in Sweden, Dr. Ralph Florentin-Nielsen of the Copenhagen University Observatory in Denmark, Dr. Kari Lumme of the University of Helsinki in Finland but currently working at the University of Massachusetts, Dr. Richard Norton and Mr. Richard Willey of the Flandrau Planetarium of the University of Arizona, Dr. N. K. Reay and Dr. Susan Worswick of the Astronomy Group in the Physics Department at Imperial College London, Dr. Tony Maxworthy of the University of Southern California at Los Angeles, Professor David B. Beard of the Physics Department of the University of Kansas, Dr. Joseph Veverka of the Laboratory for Planetary Studies at Cornell University, Mr. Herschel Gunawardena of the Astronomical Society of Ceylon, Dr. Donald Osterbrock of the Lick Observatory at the University of California in Santa Cruz, Professor Bart Bok of the University of Arizona in Tucson, Professor George Field of the Harvard College Observatory, Mr. Graham Browne from the University of Leicester in England, Dr. Brian Morgan and Mr. David Youll of the Astronomy Group in the Physics Department at Imperial College London, Dr. Rudy Hanel of the Goddard Space Flight Center in Maryland, Dr. William McKinney of the Geography-Geology Department at the University of Wisconsin at Stevens Point, and Dr. William Hartmann of the Planetary Science Institute in Tucson.

Elvius was here for several weeks using the PDP-11 computer for the reduction of polarimetric observations. Nielsen was here for four weeks working with Baum on the experiment for testing the constancy of the physical constants. Lumme spent about a week working with our Joyce-Loebl microphotometer investigating the question of non-uniformity and asymmetry in Saturn's rings. Reay and Worswick, and later Morgan and Youll, were here for several weeks working with Baum on the Spectracon observations that included the satellites of Uranus and Neptune. Maxworthy searched the photographic collection for Jupiter images that show features testing a theoretical dynamical model of the Jovian atmosphere that he and a colleague have developed mathematically. Bok, Osterbrock, and Field familiarized themselves with Planetary Center programs and served as a Visiting Committee to the Observatory for the purpose of recommending long-term plans. Browne, who was here for six months last year, returned for a few days to clean up a few loose ends in his earlier work with Jupiter images. McKinney arrived to begin a two-month stay working with Leonard Martin on the analysis of Martian north polar hood data. Hartmann was here for a week looking at Mars photographs and discussing Mars topics with our staff. Others listed in the preceding paragraph but not in this one were at the Planetary Center on short visits of only a day or two, generally to select photographic material.

IX. NASA TEAMS AND COMMITTEES

Baum has continued to serve on the Viking Orbiter Imaging Science Team, with some assistance from Thompson. Baum is also a member of the Viking Landing Site Staff. Upcoming Planetary Center activities that may prove helpful to Viking include the production of ground-based Martian albedo maps by Inge and the photoelectric measurement of Martian polarization by Bowell. The latter offers the possibility of detecting the presence of obscuring dust in the Martian atmosphere up to a relatively few weeks before Viking arrives.

Baum has also continued as a member of the LST Detector Working Group and a consultant to the LST High Resolution Camera Team. Committee and Team participations have been funded separately from this grant.

X. FINANCIAL STATUS

Routine monthly expenditures have been running close to the budgeted level. No unusual expenses occurred during the six months covered by this report, nor do we anticipate any during the remainder of the year. No foreign travel was charged to this grant during the current report period, but we have set up plans for sending one Patrol observer (Ferguson) to Cerro Tololo for ten weeks beginning in November and ending in January.

XI. PUBLICATIONS AND PRESENTATIONS

The following is a list of papers that appeared in print or that were in press (accepted for publication) during the twelve months ending 30 June 1975. Papers which appeared in the present six-month reporting period are indicated by asterisks, while those newly in press during the same period are indicated by daggers.

Baum, W. A. (1973a). Planetary Research Center at the Lowell Observatory. Trans. I.A.U. 15A, 200.

Baum, W. A. (1973b). International Planetary Patrol Program. Trans. I.A.U. 15A, 199.

Baum, W. A. (1974a). Earth-based observations of Martian albedo changes. Icarus 22, 363.

Baum, W. A. (1974b). Results of current Mars studies at the IAU Planetary Research Center. In IAU Symposium No. 65, Exploration of the Planetary System (C. Iwaniszewska and A. Woszczyk, eds.), pp. 241-251. D. Reidel Publishing Company, Dordrecht, The Netherlands.

Baum, W. A., and Ferguson, H. M. (1974). A four-year comparison of astronomical observing conditions at seven observatories. Bull. Amer. Astron. Soc. 6, 487.

*Bowell, E. L. G. (1975). Short-term periodic variations in the polarization [of Venus]. In The Atmosphere of Venus. Proceedings of a Conference, October 15-17, 1974. Goddard Institute for Space Studies, New York.

Boyce, P. B. (1975). Mars 1971: Photometric behavior of the Martian dust. Icarus, submitted for publication.

Capen, C. F. (1974). A Martian yellow cloud--July 1971. Icarus 22, 345.

Dollfus, A., Camichel, H., Boyer, C., Aurière, M., Bowell, E., and Nikander, J. (1975). Photometry of Venus: I. Observation of the brightness distribution over the disk. Icarus, submitted for publication.

*Franz, O. G. (1975). A photoelectric color and magnitude of Mimas. Bull. Amer. Astron. Soc. 7, 388.

Franz, O. G., and Millis, R. L. (1974a). A search for post-eclipse brightening of Io with an area-scanning photometer. Bull. Amer. Astron. Soc. 6, 383.

Franz, O. G., and Millis, R. L. (1974b). A search for posteclipse brightening of Io with an area-scanning photometer. II. Icarus 23, 431.

*Franz, O. G., and Millis, R. L. (1975). Photometry of Dione, Tethys, and Enceladus on the UBV system. Icarus 24, 433-442.

Hall, J. S., and Riley, L. A. (1974). A photometric study of Saturn and its rings. Icarus 23, 144.

Inge, J. L. (1974). Mars - 1973 (Albedo map, 1:25,000,000). Lowell Obs. Map Series.

Martin, L. J. (1974a). The major Martian dust storms of 1971 and 1973. Icarus 23, 108.

Martin, L. J. (1974b). The major Martian yellow storm of 1971. Icarus 22, 175.

*Martin, L. J. (1975a). Apparent changes in the north polar hood of Mars during dust storms. Bull. Amer. Astron. Soc. 7, 369.

†Martin, L. J. (1975b). North polar hood observations during Martian dust storms. Icarus, submitted for publication.

Martin, L. J., and McKinney, W. M. (1974). North polar hood of Mars in 1969 (May 18-July 25). I. Blue light. Icarus 23, 380.

†Millis, R. L., and Thompson, D. T. (1975a). UBV photometry of the Galilean satellites. Icarus, in press.

*Millis, R. L., and Thompson, D. T. (1975b). Recent UBV photometry of the Galilean satellites. Bull. Amer. Astron. Soc. 7, 237-238.

Millis, R. L., Thompson, D. T., Harris, B. J., Birch, P., and Sefton, R. (1974a). A search for post-eclipse brightening of Io with multiple-aperture photometers. Bull. Amer. Astron. Soc. 6, 383.

Millis, R. L., Thompson, D. T., Harris, B. J., Birch, P., and Sefton, R. (1974b). A search for posteclipse brightening of Io in 1973. I. Icarus 23, 425.

*Wasserman, L. H., and Baum, W. A. (1975). Analysis of Earth-based planetary images thru digitization. Bull. Amer. Astron. Soc. 7, 389.

†Zellner, B., Wisniewski, W., Andersson, L., and Bowell, E. (1975). Minor planets and related objects, UBV photometry and surface composition. Lunar and Planetary Laboratory, University of Arizona, Tucson. Astron. J., submitted for publication.

Papers presented at society meetings during this report period included the following:

At the AAS Division of Planetary Sciences meeting at Columbia (Maryland) in February:

L. J. Martin, "Apparent Changes in the North Polar Hood of Mars During Dust Storms"

L. H. Wasserman and W. A. Baum, "Analysis of Earth-Based Planetary Images thru Digitization"

O. G. Franz, "A Photoelectric Color and Magnitude of Mimas"

C. F. Capen, "History of Martian Cartography and Nomenclature" (an informal evening historical session).

At the American Astronomical Society meeting in Bloomington (Indiana) in March:

R. L. Millis, "Recent UBV Photometry of the Galilean Satellites."

At the Jupiter Conference at Tucson (Arizona) in May:

W. A. Baum, L. H. Wasserman, and J. L. Inge, "The Observed Flow Pattern of the Jovian Cloud Deck."